Meningiomas of the Tuberculum and Diaphragma Sellae

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Abstract

Introduction Although tuberculum sellae (TS) and diaphragma sellae (DS) meningiomas have different anatomical origins, they are frequently discussed as a single entity. Here we review the radiologic and intraoperative findings of TS and DS meningiomas and propose a radiologic classification.

Methods We retrospectively reviewed 10 consecutive TS and DS meningiomas. Data regarding clinical presentation, preoperative imaging, and intraoperative findings were analyzed. Three sellar dimensions were measured on magnetic resonance imaging (MRI): the tuberculum-sellar floor interval (TSFI), the planum-tuberculum interval (PTI), and the total height.

Results Three distinct anatomical patterns were recognized: exclusively tubercular meningiomas (type A) were accompanied by elongation of the TSFI and, more significantly, of the PTI; combined TS and DS meningiomas (type B) were associated with relative elongation of both the PTI and TSFI; and the sole exclusively DS meningioma (type C) was associated with elongation of neither PTI nor TSFI.

Conclusion Suprasellar meningiomas can be classified as tubercular, combined, or diaphragmatic based on preoperative MRI. Exclusively tubercular meningiomas (type A) require only a supradiaphragmatic approach. Tumor involvement of the sellar diaphragm (type B or C) requires resection of the diaphragm and thus a combined infra- and supradiaphragmatic approach.

Keywords
- tuberculum sellae
- diaphragma sellae
- planum sphenoidale
- meningioma
- classification
- endoscopic
- endonasal

Introduction

Tuberculum sellae (TS) and diaphragma sellae (DS) meningiomas represent 5–10% of all intracranial meningiomas.[1–4] They are traditionally grouped together with other suprasellar meningiomas including the more anterior planum sphenoidale (PS) meningiomas.[4–6] Even though TS and DS meningiomas have different sites of origin that can be distinguished anatomically, they are often grouped together as TS meningiomas.[3–5,7] The differentiation between these two types is confounded by similarity in clinical presentation and anatomical adjacency.[8–10] True TS meningiomas are more common than DS meningiomas.[3,5,10] In a series of 67 anterior cranial fossa meningiomas, 25 were classified as TS meningiomas and only one as a DS meningioma.[5]

The location of suprasellar meningiomas at the central skull base and their proximity to critical surrounding neurovascular structures pose challenges to the surgeon.[3,11,12] Most can be approached transcranially from "above" or transnasally from "below."[1,11–14] Here we analyze the

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radiologic and intraoperative findings of TS and DS meningiomas and propose a radiologic classification to guide the endoscopic surgical resection of these tumors.

Methods

We retrospectively reviewed 10 consecutive cases of resected TS and DS meningiomas utilizing an endoscopic endonasal transsphenoidal (EET) approach. PS, parasellar, and sphenoid wing meningiomas were excluded. Tumors originating anterior to the chiasmatic sulcus (CS) or having most of the tumor anterior to the CS were considered PS meningiomas and excluded from the study. Data regarding clinical presentation, preoperative imaging, and intraoperative findings were analyzed.

On T1-weighted midsagittal magnetic resonance imaging (MRI), we were able to identify three osseous points: P, the posterior planum point, the most superior point of the posterior PS; T, the tuberculum, the most posterior point beneath the CS (and the most common point of attachment of the diaphragma), and C, the clival-sellar floor point, the junction of clivus and sellar floor (►**Fig. 1A**, **B**).

The tuberculum-sellar floor interval (TSFI) was used to estimate the sagittal height of the sellar face. The more superior expanse incorporating the tuberculum and CS was estimated by measuring the planum-tuberculum interval (PTI) (►**Fig. 1C**). We then calculated the total height (TH) as PTI + TSFI. These measurements were compared with those derived from MRIs of 10 randomly chosen patients without sellar or parasellar pathology. A one-tailed *t* test was used for statistical analysis.

A clear line of distinction between the tumor and the pituitary gland, a radiologic distinction line (RDL), was sought on the same midline sagittal T1-weighted gadolinium-enhanced MRI; it was considered to be either present (clear) or absent (unclear). The position of the optic chiasm (OC) in relation to the tumor was evaluated on midsagittal MRI. The relationship of the tumor to the proximal intracranial optic nerves (ONs) and tumor extension into the optic canals on coronal T1-weighted gadolinium-enhanced MRIs were also noted.

Intraoperatively, the patency of the anterior intercavernous sinus (AIS), tumor involvement of the DS, and the tumor's extension into the optic canals were evaluated. The AIS was considered either patent, absent (occluded), or not reported. The DS was considered either involved by tumor, adherent, or separate. The extension of tumor in each optic canal ($n = 20$) was noted. Discrepancies between preoperative imaging and intraoperative findings were tabulated.

Results

In the meningioma group, the PTI, TSFI, and TH means were 7.8 mm (range: 2–15.6 mm) and 9.4 mm (range: 3.9–13 mm), and 17.2 mm (range: 5.9–26.5 mm), respectively. In the control group, the PTI, TSFI, and TH means were 3.3 mm (range: 1.9–6.9 mm) and 8.2 mm (range: 6.1–10.9 mm), and 11.5 mm (range: 8.2–13.9 mm), respectively. The differences in PTI and TH, but not that in TSFI, were statistically significant ($p < 0.05$). ►**Table 1** summarizes the patients' characteristics. In relation to tumor, the chiasm was posterior in two, superoposterior in four, superior in three, and posteroinferior in one case. The intracranial ONs were located superior in three, superolateral in four, and lateral in three cases in relation to tumor. MRI showed tumor extension into 45% (9 of 20) of the optic canals. In the optic canals, the tumor was inferior to the ON in two, inferomedial in two, medial in one, and superior-medial-inferior in three cases. The intraoperative findings of tumor location in the optic canals correlated with the preoperative MRI findings in all cases. The AIS was patent in six cases, occluded in two, and not reported in two. The DS was involved in five cases, adherent in three, and separate in two.

Three distinct patterns were recognized in this cohort. True TS meningiomas (type A; $n = 5$) are associated with elongation of the TS (►**Fig. 1D–G**). Their PTI, TSFI, and TH means were 10.8 mm (range: 4–15.6 mm) and 10.2 (range: 8.4–13 mm), and 21 mm (range: 12.4–26.5 mm), respectively. The differences between PTI, TH, and TSFI for true TS meningiomas and controls were all statistically significant ($p < 0.05$). More than half of the elongation in TH is attributed to the PTI, indicating significant elongation in the TS-CS compartment. In type A tumors, the AIS was always patent, the DS was not involved by tumor, and the chiasm was posterior or superoposterior. The intracranial ONs were most commonly displaced laterally by tumor. These tumors extended into 50% of the optic canals (5 of 10), and that extension was usually medial and superior and/or inferior. All type A meningiomas had a clear line of distinction between tumor and pituitary gland on MRI.

TS-DS meningiomas (type B) are associated with relative elongation of both PTI and TSFI (►**Fig. 1H–K**). Their PTI, TSFI, and TH means were 5.6 mm (range: 3.2–8.6 mm), 9.7 (range: 8.7–12 mm), and 15.3 mm (range: 11.9–20.6 mm), respectively. Although all parameters were elongated compared with those of the control group, none of the differences reached statistical significance. The AIS was usually occluded, the DS was involved by tumor, the OC was superior to tumor, the ONs were superior or superolateral in relation to tumor, and tumor extension into the canal was seen in 50% of cases ($n = 4$ of 8). Tumor in the canal was usually inferior or, less commonly, medial within the OC. Only one of four type B meningiomas had a clear line of distinction between tumor and pituitary gland on MRI.

Only one tumor was a true DS meningioma (type C). The PTI, TSFI, and TH were 2 mm, 3.9 mm, and 5.9 mm, respectively. These measurements are similar to those of the control group. In this case, the AIS was patent, the DS was involved by tumor, the chiasm was superior, the ONs were lateral to tumor, and the tumor did not extend into the optic canals (►**Fig. 1J–L**).

Discussion

Suprasellar meningiomas have been classified by site of origin into three subtypes: PS, TS, and DS meningiomas.[3,10] The most common is TS meningioma, followed by PS

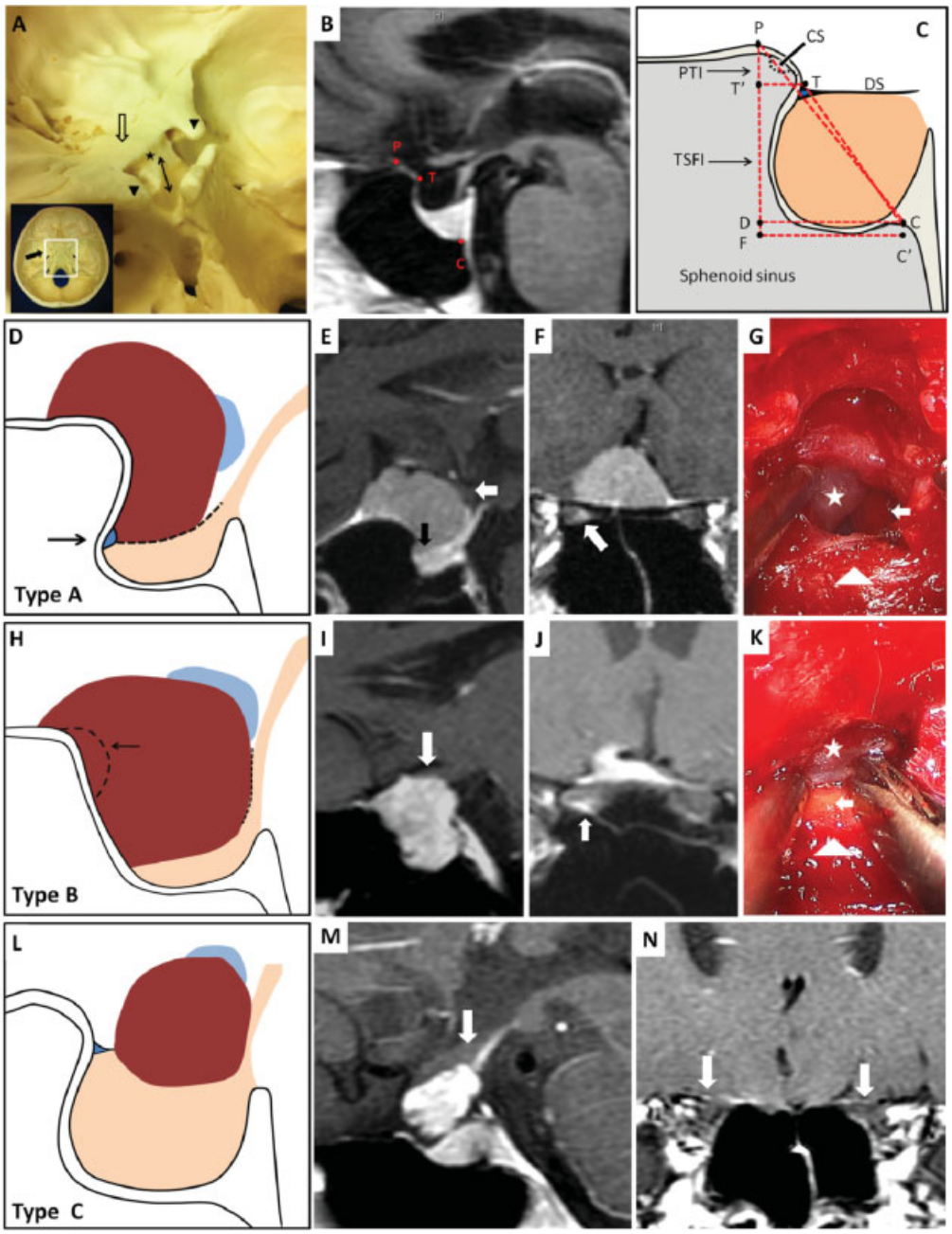

Fig. 1 (A) Intracranial superolateral sellar view. The planum sphenoidale (empty arrow) is separated posteriorly from the tuberculum sella (TS) by the chiasmatic sulcus (star). The double-ended arrow extends from the chiasmatic sulcus (CS) to the TS to the nadir of the sellar floor. Both anterior clinoid processes are seen (arrowheads). (B) Normal midsagittal T1-weighted gadolinium-enhanced magnetic resonance imaging (MRI) showing the points: P, the posterior planum point, T, the tuberculum, and C, the clival-sellar floor point. (C) Drawing showing the measured dimensions: planum-tuberculum interval (PTI) and tuberculum-sellar floor Interval (TSFI). The CS (dotted black line) can be difficult to identify on sagittal MRIs. The anterior intercavernous sinus (AIS) (dark blue) is located in the anterior leaflets of the diaphragma sellae (DS) at its attachment to the TS. The DS is attached to the TS at or below the tubercular recess. To estimate the TSFI and the PTI, we outlined a right angle triangle P-D-C with hypotenuse P-C and a right angle at D. We then drew two lines parallel to D-C, T-T′, intersecting PD at T′, and F-C′ passing through the most inferior point of the sellar floor to intersect the line P-D at F and ending at C′ (in the coronal plane of C). P-T′ is the length of PTI, and T′-F is the length of TSFI. We then calculated the total height (TH) as PTI + TSFI. (D–G) True TS meningioma (type A). (D)The PTI is elongated, the AIS is patent, the chiasm is superoposterior, and an intact DS (dotted line) separates tumor from pituitary gland. The black arrow points to the patent AIS. (E) Sagittal MRI showing the chiasm (white arrow) and a line of distinction between tumor and pituitary gland (black arrow). (F) Coronal MRI showing right intracanalicular tumor (arrow). (G) Intraoperative images showing the extracapsular dissection of the meningioma (star) via a supradiaphragmatic approach. The tumor was easily separated from the DS. The dura covering the gland was kept intact (arrowhead).The pituitary stalk can be seen posteriorly (arrow). (H–K) Tuberculum-diaphragma sella meningioma (type B). (H)The TH is elongated, the AIS is absent, the chiasm is superior, and the DS is involved by tumor. The TS intracranial face can be effaced ($n = 2/4$) (arrow). (I) Sagittal MRI showing the chiasm (white arrow) and no clear distinction between tumor and pituitary gland.(J) Coronal MRI showing right intracanalicular tumor (arrow).(K) Intraoperative images showing the supra- and infradiaphragmatic approach used. The tumor involving the DS is being resected (star). The dura covering the gland was opened for an inferior approach and the gland is exposed (arrow). Part of the inferior dura covering the gland (arrowhead) was kept intact. (L–N) True DS meningioma (type C). (L) The AIS is patent, the chiasm is superior, and the DS is involved by tumor. (M) Sagittal MRI showing the chiasm (white arrow) and a clear line of distinction between tumor and pituitary gland. (N) Coronal MRI showing no intracanalicular tumor extension (arrows).

Table 1 Ten cases of tuberculum-diaphragma sella meningiomas[a]

Case	Age, y	Sex	Presenting symptom	Size, cm^3	Location of ON[b]	Location of chiasm[b]	Tumor in the right optic canal	Tumor in the left optic canal	RDL	PTI	TSFI	TH	AIS	DS
1	51	F	Unilateral visual loss	6.2	Superolateral	Posterior	Inferior-medial-superior	Superomedial	Clear	10.8	13	23.8	Present	Separate
2	32	F	Unilateral visual loss	1.2	Superior	Superoposterior	No tumor	Inferior-medial-superior	Not clear	8.6	12	20.6	Occluded	Involved
3	53	F	Unilateral visual loss	5.8	Superolateral	Posterior	Inferior-medial	No tumor	Clear	8.8	9.3	18.1	Present	Separate
4	49	F	Galactorrhea	3.9	Superior	Superior	No tumor	Inferior	Not clear	3.3	9	12.3	Occluded	Involved
5	67	F	Vertigo	0.5	Superior	Superior	No tumor	No tumor	Clear	2	3.9	5.9	Present	Involved
6	72	F	Unilateral visual loss	3.9	Superolateral	Superior	Inferior	No tumor	Not clear	7.3	9	16.3	Not reported	Involved
7	45	F	Unilateral visual loss	8.3	Lateral	Inferior-posterior	Medial	No tumor	Clear	14.6	9.4	24	Present	Adherent
8	59	M	Peripheral visual loss	5.9	Superolateral	Superoposterior	Inferior-medial	No tumor	Clear	3.2	8.7	11.9	Not reported	Involved
9	52	F	Headache	0.7	Lateral	Superoposterior	No tumor	No tumor	Clear	4	8.4	12.4	Present	Adherent
10	64	M	Unilateral visual loss	9.2	Lateral	Superoposterior	Inferior-medial-superior	No tumor	Clear	15.6	10.9	26.5	Present	Adherent

Abbreviations: AIS, anterior intercavernous sinus; DS, diaphragm sellae; ON, optic nerve; PTI, planum-tuberculum interval; RDL, MRI radiologic distinction line between tumor and gland; TH, total height; TSFI, tuberculum-sellar floor interval.

[a]Age listed is at the time of the first surgical intervention. All measurements are in millimeters.

[b]Location of optic chiasm and ON in relation to the tumor and the position of tumor within the optic canal in relation to the ONs. Tumor size was estimated as the product of perpendicular maximum diameters.

meningioma.[5] True DS meningiomas are rare.[3,5,10] Although PS meningiomas can be confused with TS and DS meningiomas in a clinical evaluation, they can be differentiated radiologically by evaluating the tumor's relationship to surrounding bone and neurovascular structures. The more anterior site of origin of PS tumors leads to posterior and inferior displacement of the ONs and chiasm and the anterior cerebral arteries complex; this can be seen on preoperative imaging.[2,6] Two PS meningiomas, resected endoscopically during the period of study, were excluded from our analysis. Their main tumor volume was anterior to the CS. In these two cases, the OC and the pituitary stalk were not displaced by tumor. Although PS meningiomas can mimic TS and DS meningiomas at presentation, especially when large, we suggest separating them for analysis.

Most PS meningiomas do not extend below the planum level to involve the DS; they are thus easily exposed by a low subfrontal or pterional craniotomy. The more inferior point of origin of TS and DS meningiomas, in contrast, especially those cases in which the tuberculum is elongated, require greater inferior dissection below and at an angle perpendicular to the PS. Prior to expanded transsphenoidal approaches, tumors inferior to the planum were accessed from above through the superoposterior sphenoid sinus.[15] More recently, many surgeons have found this region more accessible using an EET approach. Recent reviews comparing transcranial and endoscopic transnasal resection of TS meningiomas failed to show the superiority of one approach versus the other in regard to visual outcomes. Each approach had its own specific morbidities. In general, the endoscopic transnasal approach seemed to offer the trade-off of lower complication rates for less complete tumor resection relative to transcranial approaches.[11,16–19] Distinction among our three classes of suprasellar meningiomas, which differ in regard to points of origin, predominant regions of dural involvement, sources of blood supply, and relationships to neurovascular neighbors, is particularly relevant to these transsphenoidal approaches. Elongation of the TS was alluded to in early reports of suprasellar meningiomas.[3] Such elongation and any accompanying sellar expansion facilitate approach to the tumor from below via a transnasal route.[20]

In a cadaveric study of 50 adult sellar regions, the sellar depth, defined as the greatest distance between the floor and a perpendicular line connecting the TS and DS, ranged from 5 to 12 mm with a mean of 9 mm.[21] A more recent study used T1-weighted MRI to measure sellar face, defined as the distance from the TS to the sellar-clival point. This distance ranged from 6.7 to 19.8 mm with a mean of 13.4 mm.[20] This distance represents the line connecting point T to point C in ►**Fig. 1C**. This distance ranged from 7.3 to 15.3 mm with a mean of 11.2 mm in our control group. The TS is usually defined as the bony prominence inferior to the CS; it corresponds to the tuberculum recess in 50% of patients.[22] The inferior limit of the TS separating it from the sella turcica or the sellar floor is not well defined.

To evaluate the vertical elongation of the sella, tuberculum, and the CS, we calculated the PTI and the TSFI. The PTI represents the height of the CS and the superior part of the TS above point T, which usually lies at or above the insertion of the DS (►**Fig. 1C**). The TSFI represents the sellar height starting from the floor inferiorly to the tuberculum (point T). We can conclude that PTI and TSFI represent the supradiaphragmatic (suprasellar) and infradiaphragmatic (sellar) heights, respectively. The sella was expanded in our meningioma group, as evidenced by an increased TH relative to that in controls (a mean of 17.2 mm versus 11.5 mm; $p < 0.05$). In type A meningiomas, both PTI and TSFI are elongated representing elongation of both the sellar and, more significantly, the suprasellar compartment. In type B, the sellar and the suprasellar compartments had equally distributed elongation.

Analysis of tumor displacement of neurovascular structures, tumor involvement of the DS, and patency of the AIS showed two distinctive patterns. In group A, the OC was displaced posteriorly and the ON nerves laterally, indicating a tumor origin more superior than in group B. In group B, the OC was displaced superior and the ON superior-lateral. The tumor extension in the optic canals of group A was medial and both superior and inferior to the ONs. In contrast, intracanalicular extension in group B was mainly inferior to the ON. In group A, the DS was spared and the AIS was always patent, whereas in group B the AIS was occluded (occluded in two, not reported in two), and the DS was involved. These findings suggest that type A tumors can be approached by craniotomy from above or transnasally from below but type B tumors might best be approached from below.

The AIS is present in 76% of healthy individuals.[21] It is usually located in the DS leaflets along its attachments to the TS, which correspond to the tubercular recess.[22] In all five type A tumors, the AIS was patent. This suggests lack of involvement by tumor, consistent with the lack of involvement of the DS as well. In such cases, division and resection of the AIS and more posterior DS will not be necessary; a purely supradiaphragmatic endoscopic approach should be sufficient for complete resection of these tumors. This supradiaphragmatic route avoids sacrificing the AIC, maintains the DS as a barrier between tumor and gland, and limits manipulation of the pituitary gland during tumor resection. We recommend starting with a supradiaphragmatic approach that keeps the AIS intact. In two cases in group A, an intact arachnoid plane facilitated separating tumor from the DS. In the other three cases, the tumor was attached to but easily dissected from the DS. Should the AIS be involved with tumor or should the tumor incorporate the DS, a more inferior trajectory through the AIS can be taken. In group B tumors, the AIS is occluded and the DS is involved; this mandates supra- and infradiaphragmatic access to remove the tumor completely.

Only one case in our series was a true DS meningioma. In this case, the sellar dimensions were similar to those of our control group. Kinjo et al classified DS meningiomas into three subtypes according to the tumor's relations to the DS and pituitary stalk.[10] Type A, originating from the upper leaf of the DS anterior to the pituitary stalk; type B, originating posterior to the pituitary stalk; and type C, originating from the inferior leaf of the DS. The differentiation between types A

and C, both anterior to the stalk, can be difficult on preoperative imaging. In both cases, a combined infra- and supradiaphragmatic approach is needed for resection.

The sellar dimensions, ON location, OC displacement, and intracanalicular tumor can be difficult to analyze on preoperative imaging in larger tumors. In these cases, identification of a line of distinction between tumor and pituitary gland, the RDL, on sagittal T1-weighted gadolinium-enhanced MRIs can be useful. Type B tumors lacked this line except for one case in which a line was perceived on preoperative MRI but intraoperative inspection showed the DS to be involved and transgressed by tumor.

TS-DS meningiomas can thus be classified into three groups on the basis of routine preoperative MRI. These subtypes have different anatomical relationships to surrounding neurovascular structures. For type A tumors, an endoscope transsphenoidal supradiaphragmatic approach should suffice for complete resection. For type B tumors, a combined infra- and supradiaphragmatic approach is needed. Exclusively DS meningiomas (type C) are rare. The major limitations of our study was its retrospective design and the small number of cases analyzed. Further prospective evaluations are required to validate these radiologic findings in differentiating subtypes of TS and DS meningiomas and the usefulness of this classification.

References

1 Soni RS, Patel SK, Husain Q, Dahodwala MQ, Eloy JA, Liu JK. From above or below: the controversy and historical evolution of tuberculum sellae meningioma resection from open to endoscopic skull base approaches. J Clin Neurosci 2014;21(4):559–568

2 Jallo GI, Benjamin V. Tuberculum sellae meningiomas: microsurgical anatomy and surgical technique. Neurosurgery 2002;51(6): 1432–1439; discussion 1439–1440

3 Al-Mefty O, Holoubi A, Rifai A, Fox JL. Microsurgical removal of suprasellar meningiomas. Neurosurgery 1985;16(3):364–372

4 Chan RC, Thompson GB. Morbidity, mortality, and quality of life following surgery for intracranial meningiomas. A retrospective study in 257 cases. J Neurosurg 1984;60(1):52–60

5 Rubin G, Ben David U, Gornish M, Rappaport ZH. Meningiomas of the anterior cranial fossa floor. Review of 67 cases. Acta Neurochir (Wien) 1994;129(1–2):26–30

6 Nanda A, Ambekar S, Javalkar V, Sharma M. Technical nuances in the management of tuberculum sellae and diaphragma sellae meningiomas. Neurosurg Focus 2013;35(6):E7

7 de Divitiis E, Esposito F, Cappabianca P, Cavallo LM, de Divitiis O, Esposito I. Endoscopic transnasal resection of anterior cranial fossa meningiomas. Neurosurg Focus 2008;25(6):E8

8 Kwancharoen R, Blitz AM, Tavares F, Caturegli P, Gallia GL, Salvatori R. Clinical features of sellar and suprasellar meningiomas. Pituitary 2014;17(4):342–348

9 Leu CH, Hu TL, Shen CC, Wang YC. Tuberculum sellae meningiomas: clinical manifestation, radiologic diagnosis, surgery and visual outcome. Zhonghua Yi Xue Za Zhi (Taipei) 1998;61(1):1–7

10 Kinjo T, al-Mefty O, Ciric I. Diaphragma sellae meningiomas. Neurosurgery 1995;36(6):1082–1092

11 Nakamura M, Roser F, Struck M, Vorkapic P, Samii M. Tuberculum sellae meningiomas: clinical outcome considering different surgical approaches. Neurosurgery 2006;59(5):1019–1028; discussion 1028–1029

12 Fernandez-Miranda JC, Pinheiro-Nieto C, Gardner PA, Snyderman CH. Endoscopic endonasal approach for a tuberculum sellae meningioma. J Neurosurg 2012;32(Suppl):E8

13 Prosser JD, Vender JR, Alleyne CH, Solares CA. Expanded endoscopic endonasal approaches to skull base meningiomas. J Neurol Surg B Skull Base 2012;73(3):147–156

14 Chowdhury FH, Haque MR, Goel AH, Kawsar KA. Endoscopic endonasal extended transsphenoidal removal of tuberculum sellae meningioma (TSM): an experience of six cases. Br J Neurosurg 2012;26(5):692–699

15 Patterson RH Jr, Danylevich A. Surgical removal of craniopharyngiomas by the transcranial approach through the lamina terminalis and sphenoid sinus. Neurosurgery 1980;7(2):111–117

16 Clark AJ, Jahangiri A, Garcia RM, et al. Endoscopic surgery for tuberculum sellae meningiomas: a systematic review and meta-analysis. Neurosurg Rev 2013;36(3):349–359

17 Komotar RJ, Starke RM, Raper DM, Anand VK, Schwartz TH. Endoscopic endonasal versus open transcranial resection of anterior midline skull base meningiomas. World Neurosurg 2012; 77(5–6):713–724

18 Hayhurst C, Teo C. Tuberculum sella meningioma. Otolaryngol Clin North Am 2011;44(4):953–963, viii–ix

19 Chokyu I, Goto T, Ishibashi K, Nagata T, Ohata K. Bilateral subfrontal approach for tuberculum sellae meningiomas in long-term postoperative visual outcome. J Neurosurg 2011; 115(4):802–810

20 Zada G, Agarwalla PK, Mukundan S Jr, Dunn I, Golby AJ, Laws ER Jr. The neurosurgical anatomy of the sphenoid sinus and sellar floor in endoscopic transsphenoidal surgery. J Neurosurg 2011;114(5): 1319–1330

21 Renn WH, Rhoton AL Jr. Microsurgical anatomy of the sellar region. J Neurosurg 1975;43(3):288–298

22 Peris-Celda M, Kucukyuruk B, Monroy-Sosa A, Funaki T, Valentine R, Rhoton AL Jr. The recesses of the sellar wall of the sphenoid sinus and their intracranial relationships. Neurosurgery 2013;73; (2, Suppl Operative):117–131; discussion 131